

(NO) NEW PHYSICS IN B_s MIXING AND DECAY

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The status of possible new-physics signals in $B_{s,d}$ -meson mixing and decay is reviewed. In particular, it is emphasized that the recent LHCb results, that find no evidence for a non-standard phase in B_s - \bar{B}_s mixing, make a consistent explanation of the $D\bar{O}$ data on the like-sign dimuon charge asymmetry notoriously difficult. In order to clarify the inconclusive experimental situation, independent measurements of the semileptonic asymmetries are needed.

1 Introduction

The phenomenon of neutral B_s -meson mixing is encoded in the off-diagonal elements M_{12}^s and Γ_{12}^s of the mass and decay rate matrix. These two complex parameters can be fully determined by measuring the mass difference $\Delta M_s = M_H^s - M_L^s$, the CP-violating phase $\phi_{J/\psi\phi}^s = -2\beta_s$, the decay width difference $\Delta\Gamma_s = \Gamma_L^s - \Gamma_H^s$, and the CP asymmetry a_{fs}^s in flavor-specific decays.

The combined Tevatron and LHC determination of the mass difference reads^{1,2}

$$\Delta M_s = (17.73 \pm 0.05) \text{ ps}^{-1}, \quad (1)$$

and agrees well with the corresponding standard model (SM) prediction³

$$(\Delta M_s)_{\text{SM}} = (17.3 \pm 2.6) \text{ ps}^{-1}. \quad (2)$$

Here the quoted errors correspond to 68% confidence level (CL) ranges.

The phase difference $\phi_{J/\psi\phi}^s$ between the B_s mixing and the $b \rightarrow sc\bar{c}$ decay amplitude and the width difference $\Delta\Gamma_s$ can be simultaneously determined from an analysis of the flavor-tagged time-dependent decay $B_s \rightarrow J/\psi\phi$. Such measurements have been performed by CDF, $D\bar{O}$, and recently also by LHCb. Combining 1 fb^{-1} of $B_s \rightarrow J/\psi\phi$ and $B_s \rightarrow J/\psi f_0$ data the LHCb collaboration finds⁴

$$\phi_{J/\psi\phi}^s = (-0.11 \pm 5.0)^\circ, \quad \Delta\Gamma_s = (0.116 \pm 0.019) \text{ ps}^{-1}. \quad (3)$$

The corresponding numbers in the SM are³

$$(\phi_{J/\psi\phi}^s)_{\text{SM}} = \arg \left[\frac{(V_{ts}^* V_{tb})^2}{(V_{cs}^* V_{cb})^2} \right] = (-2.1 \pm 0.1)^\circ, \quad (\Delta\Gamma_s)_{\text{SM}} = (0.087 \pm 0.021) \text{ ps}^{-1}, \quad (4)$$

and again agree well with the observations with the results for $\Delta\Gamma_s$ differing by 1.0σ .

The CP asymmetry in flavor-specific decays a_{fs}^s can be extracted from a measurement of the like-sign dimuon charge asymmetry A_{SL}^b , which involves a sample that is almost evenly composed of B_d and B_s mesons. Employing 9.0 fb^{-1} of data the $D\bar{O}$ collaboration obtains⁵

$$A_{\text{SL}}^b = (-7.87 \pm 1.96) \cdot 10^{-3}. \quad (5)$$

Utilizing the SM predictions for the individual flavor-specific CP asymmetries³

$$(a_{fs}^d)_{\text{SM}} = -(4.1 \pm 0.6) \cdot 10^{-4}, \quad (a_{fs}^s)_{\text{SM}} = (1.9 \pm 0.3) \cdot 10^{-5}, \quad (6)$$

one obtains

$$(A_{\text{SL}}^b)_{\text{SM}} = (0.595 \pm 0.022) (a_{fs}^d)_{\text{SM}} + (0.406 \pm 0.022) (a_{fs}^s)_{\text{SM}} = (-2.4 \pm 0.4) \cdot 10^{-4}. \quad (7)$$

Using the measured value of the CP asymmetry in flavor-specific B_d decays⁶

$$a_{fs}^d = (-4.7 \pm 4.6) \cdot 10^{-3}, \quad (8)$$

and (5) in (7), one can also directly derive a value of a_{fs}^s . One arrives at

$$a_{fs}^s = (-1.3 \pm 0.8) \cdot 10^{-2}, \quad (9)$$

The results (5) and (7) correspond to a tension with a statistical significance of 3.9σ , while (9) differs from $(a_{fs}^s)_{\text{SM}}$ as given in (6) by 1.5σ only.

2 Model-Independent Analysis

In view of the observed departures from the SM predictions, it is natural to ask what kind of new physics is able to simultaneously explain the measured values of ΔM_s , $\phi_{J/\psi\phi}^s$, $\Delta\Gamma_s$, and a_{fs}^s . This question can be addressed in a model-independent way by parametrizing the off-diagonal elements of the mass and decay rate matrix as follows

$$\begin{aligned} M_{12}^s &= (M_{12}^s)_{\text{SM}} + (M_{12}^s)_{\text{NP}} = (M_{12}^s)_{\text{SM}} R_M e^{i\phi_M}, \\ \Gamma_{12}^s &= (\Gamma_{12}^s)_{\text{SM}} + (\Gamma_{12}^s)_{\text{NP}} = (\Gamma_{12}^s)_{\text{SM}} R_\Gamma e^{i\phi_\Gamma}. \end{aligned} \quad (10)$$

In the presence of generic new physics, the B_s -meson observables of interest are then given to leading power in $|\Gamma_{12}^s|/|M_{12}^s|$ by

$$\begin{aligned} \Delta M_s &= (\Delta M_s)_{\text{SM}} R_M, \quad \phi_{J/\psi\phi}^s = (\phi_{J/\psi\phi}^s)_{\text{SM}} + \phi_M, \\ \Delta\Gamma_s &= (\Delta\Gamma_s)_{\text{SM}} R_\Gamma \frac{\cos(\phi_{\text{SM}}^s + \phi_M - \phi_\Gamma)}{\cos\phi_{\text{SM}}^s} \approx (\Delta\Gamma_s)_{\text{SM}} R_\Gamma \cos(\phi_M - \phi_\Gamma), \\ a_{fs}^s &= (a_{fs}^s)_{\text{SM}} \frac{R_\Gamma}{R_M} \frac{\sin(\phi_{\text{SM}}^s + \phi_M - \phi_\Gamma)}{\sin\phi_{\text{SM}}^s} \approx (a_{fs}^s)_{\text{SM}} \frac{R_\Gamma}{R_M} \frac{\sin(\phi_M - \phi_\Gamma)}{\phi_{\text{SM}}^s}, \end{aligned} \quad (11)$$

where the final results for $\Delta\Gamma_s$ and a_{fs}^s have been obtained by performing an expansion in $\phi_{\text{SM}}^s = \arg(-(M_{12}^s)_{\text{SM}}/(\Gamma_{12}^s)_{\text{SM}})$. Since $\phi_{\text{SM}}^s = (0.22 \pm 0.06)^\circ$ ³ this is an excellent approximation.

The four real parameters $R_{M,\Gamma}$ and $\phi_{M,\Gamma}$ entering (10) can be constrained by confronting the observed values of ΔM_s , $\phi_{J/\psi\phi}^s$, $\Delta\Gamma_s$, and a_{fs}^s with their SM predictions. We begin our analysis by asking how well the SM hypothesis describes the data. Performing a global fit, we obtain $\chi^2 = 3.5$ corresponding to 0.7σ (1.4σ) for 4 (2) degrees of freedom (dofs). For the best-fit solution, we find instead $(R_M, \phi_M, R_\Gamma, \phi_\Gamma) = (1.02, 2^\circ, 2.9, 65^\circ)$. After marginalization the corresponding symmetrized 68% CL parameter ranges are

$$\begin{aligned} R_M &= 1.04 \pm 0.16, & \phi_M &= (-0.4 \pm 5.0)^\circ, \\ R_\Gamma &= 3.4 \pm 1.8, & \phi_\Gamma &= (56 \pm 22)^\circ. \end{aligned} \quad (12)$$

Focusing on R_Γ and ϕ_Γ , we see that a very good fit requires excessive corrections to Γ_{12}^s .

In order to further elucidate the latter point, we analyse two orthogonal hypothesis of new physics in B_s - \bar{B}_s oscillations, namely a scenario with $(M_{12}^s)_{\text{NP}} \neq 0$ and $(\Gamma_{12}^s)_{\text{NP}} = 0$ and a scenario with $(M_{12}^s)_{\text{NP}} = 0$ and $(\Gamma_{12}^s)_{\text{NP}} \neq 0$. The left (right) panel in Figure 1 shows the results of our global fit for scenario S1 (S2) in the $R_M \cos\phi_M$ - $R_M \sin\phi_M$ ($R_\Gamma \cos\phi_\Gamma$ - $R_\Gamma \sin\phi_\Gamma$) plane. From the left panel, we glean that in the scenario S1 the regions of all individual constraints apart from a_{fs}^s overlap. Minimizing the χ^2 function gives $(R_M, \phi_M) = (1.03, 2.0^\circ)$ and $\chi^2/\text{dofs} = 3.4/2$ corresponding to 1.3σ , which represents only a marginal improvement with respect to the SM

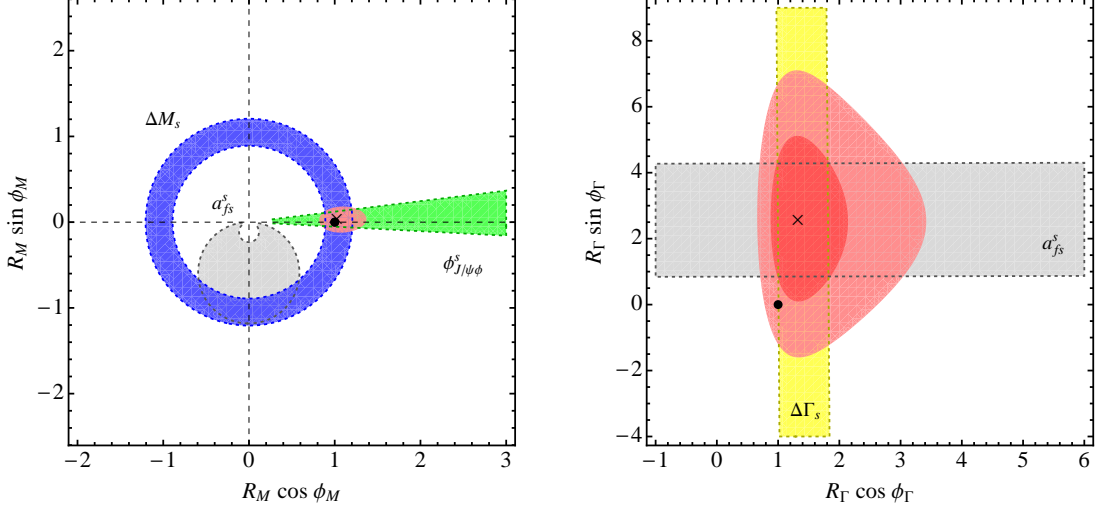


Figure 1: Left (Right): Constraints on R_M and ϕ_M (R_Γ and ϕ_Γ) in scenario S1 (S2). For the individual constraints the colored areas are 68% CL regions (dofs = 1), while for the combined fit the red (light red) area is the 68% (95%) probability region (dofs = 2). The SM values (best-fit solutions) are marked by a dot (cross).

hypothesis.^{3,7} In consequence, the case for a non-zero non-standard contribution to M_{12}^s is rather weak. By inspection of the right panel, we see that in contrast to S1, in the scenario S2 a description of the data with a probability of better than 68% is possible. The best-fit point is located at $(R_\Gamma, \phi_\Gamma) = (2.9, 62^\circ)$. In fact, the latter parameters lead to an almost perfect fit with $\chi^2/\text{dofs} = 0.2/2$ corresponding to 0.1σ . The data hence statistically favors the new-physics scenario S2 over the hypothesis S1.

3 New Physics in $b \rightarrow s\tau^+\tau^-$

The above findings suggest that one hypothetical explanation of the experimentally observed large negative values of a_{fs}^s (or equivalent A_{SL}^b) consists in postulating new physics in Γ_{12}^s that changes the SM value by a factor of 3 or more. In the following we will study whether or not and to which extend such an speculative option is viable. While in principle any composite operator $(\bar{s}b)f$, with f leading to an arbitrary flavor neutral final state of at least two fields and total mass below the B_s -meson mass, can contribute to Γ_{12}^s , the field content of f is in practice very restricted, since $B_s \rightarrow f$ and $B_d \rightarrow X_s f$ decays to most final states involving light particles are severely constrained. One notable exception is the subclass of B_s - and B_d -meson decays to a pair of tau leptons, as has been first pointed out a few years ago.⁸

The possibility of large $b \rightarrow s\tau^+\tau^-$ contributions to Γ_{12}^s , can be analyzed in a model-independent fashion⁷ by adding

$$\mathcal{L}_{\text{eff}} = \frac{4G_F}{\sqrt{2}} V_{ts}^* V_{tb} \sum_i C_i(\mu) Q_i, \quad (13)$$

to the effective $\Delta B = 1$ SM Lagrangian. Here μ denotes the renormalization scale and the Fermi constant G_F as well as the leading Cabibbo-Kobayashi-Maskawa (CKM) factor $V_{ts}^* V_{tb}$ have been extracted as global prefactors. The index i runs over the complete set of dimension-six operators with flavor content $(\bar{s}b)(\bar{\tau}\tau)$, namely $(A, B = L, R)$

$$\begin{aligned} Q_{S,AB} &= (\bar{s} P_A b) (\bar{\tau} P_B \tau), \\ Q_{V,AB} &= (\bar{s} \gamma^\mu P_A b) (\bar{\tau} \gamma_\mu P_B \tau), \\ Q_{T,A} &= (\bar{s} \sigma^{\mu\nu} P_A b) (\bar{\tau} \sigma_{\mu\nu} P_A \tau), \end{aligned} \quad (14)$$

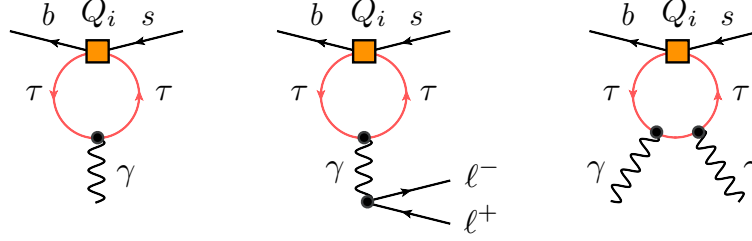


Figure 2: One-loop diagrams with a penguin insertion of a $(\bar{s}b)(\bar{\tau}\tau)$ operator (orange squares) that contribute to the processes $b \rightarrow s\gamma$ (left), $b \rightarrow s\ell^+\ell^-$ (middle), and $b \rightarrow s\gamma\gamma$ (right). The tau loop in all graphs is closed.

where $P_{L,R} = (1 \mp \gamma_5)/2$ project onto left- and right-handed chiral fields and $\sigma^{\mu\nu} = i[\gamma^\mu, \gamma^\nu]/2$.

The ten operators entering (14) govern the purely leptonic $B_s \rightarrow \tau^+\tau^-$ decay, the inclusive semi-leptonic $B \rightarrow X_s\tau^+\tau^-$ decay, and its exclusive counterpart $B^+ \rightarrow K^+\tau^+\tau^-$, making these channels potentially powerful constraints. In practice, however, flavor-changing neutral current $B_{s,d}$ decays into final states involving taus are experimentally still largely unexplored territory, so that these direct constraints turn out to be not very strong. Explicitly, one obtains

$$\begin{aligned} \mathcal{B}(B_s \rightarrow \tau^+\tau^-) &< 3\%, \\ \mathcal{B}(B \rightarrow X_s\tau^+\tau^-) &\lesssim 2.5\%, \\ \mathcal{B}(B^+ \rightarrow K^+\tau^+\tau^-) &< 3.3 \cdot 10^{-3}. \end{aligned} \quad (15)$$

Here the first limit derives⁹ from comparing the SM prediction $\tau_{B_s}/\tau_{B_d} - 1 \in [-0.4, 0.0]\%$ with the corresponding experimental result $\tau_{B_s}/\tau_{B_d} - 1 = (0.4 \pm 1.9)\%$, while the second (crude) bound follows from estimating⁷ the possible contamination of the exclusive and inclusive semileptonic decay samples by $B \rightarrow X_s\tau^+\tau^-$ events. Limits on $\mathcal{B}(B_s \rightarrow \tau^+\tau^-)$ and $\mathcal{B}(B \rightarrow X_s\tau^+\tau^-)$ of strength similar to those given in (15) also follow from charm counting¹⁰ and/or LEP searches for B decays with large missing energy.¹¹ The final number corresponds to the 90% CL upper limit on the branching ratio of $B^+ \rightarrow K^+\tau^+\tau^-$ as measured by BaBar.¹²

Further constraints on the Wilson coefficients of the $(\bar{s}b)(\bar{\tau}\tau)$ operators arise indirectly from the experimentally available information on the $b \rightarrow s\gamma$, $b \rightarrow s\ell^+\ell^-$ ($\ell = e, \mu$), and $b \rightarrow s\gamma\gamma$ transitions, because some of the effective operators introduced in (14) mix into the electromagnetic dipole operators $Q_{7,A}$ and the vector-like semileptonic operators $Q_{9,A}$. The relevant Feynman diagrams are shown in Figure 2. An explicit calculation⁷ shows that the operators $Q_{S,AB}$ mix neither into $Q_{7,A}$ nor $Q_{9,A}$, while $Q_{V,AB}$ ($Q_{T,A}$) mixes only into $Q_{9,A}$ ($Q_{7,A}$). As a result of the particular mixing pattern, the stringent constraints from the radiative decay $B \rightarrow X_s\gamma$ rule out large contributions to Γ_{12}^s only if they arise from the tensor operators $Q_{T,A}$. Similarly, the rare decays $B \rightarrow X_s\ell^+\ell^-$ and $B \rightarrow K^{(*)}\ell^+\ell^-$ primarily limit contributions stemming from the vector operators $Q_{V,AB}$. In contrast to $B \rightarrow X_s\gamma$, all $(\bar{s}b)(\bar{\tau}\tau)$ operators contribute to the double-radiative $B_s \rightarrow \gamma\gamma$ decay at the one-loop level. A detailed study⁷ shows however that the limits following from $b \rightarrow s\gamma\gamma$ are in practice not competitive with the bounds obtained from the other tree- and loop-level mediated $B_{s,d}$ -meson decays.

The model-independent 90% CL limits on the magnitudes of the Wilson coefficients are summarized in Table 1. We see that in the case of the $(\bar{s}b)(\bar{\tau}\tau)$ scalar and vector operators the allowed effects can reach almost $\mathcal{O}(1)$. These Wilson coefficients can hence be similar in size to that of the color-singlet current-current operator Q_2 , which provides the dominant contribution to Γ_{12}^s in the SM. In consequence, the corresponding suppression scale Λ is quite low, around $(1-2)$ TeV. Possible new-physics contributions to the $(\bar{s}b)(\bar{\tau}\tau)$ tensor operators are more severely constrained, because they lead to a contamination of $B \rightarrow X_s\gamma$. It is also interesting to ask which impact future improved extractions of $\mathcal{B}(B_s \rightarrow \tau^+\tau^-)$, $\mathcal{B}(B \rightarrow X_s\tau^+\tau^-)$, and $\mathcal{B}(B^+ \rightarrow K^+\tau^+\tau^-)$ will have on the limits on the Wilson coefficients $C_i(m_b)$. Such a comparison

Operator	Bound on $C_i(m_b)$	Bound on Λ	Observable
$(\bar{s} P_A b)(\bar{\tau} P_B \tau)$	0.5	2.0 TeV	$B_s \rightarrow \tau^+ \tau^-$
$(\bar{s} \gamma^\mu P_A b)(\bar{\tau} \gamma_\mu P_B \tau)$	0.8	1.0 TeV	$B^+ \rightarrow K^+ \tau^+ \tau^-$
$(\bar{s} \sigma^{\mu\nu} P_L b)(\bar{\tau} \sigma_{\mu\nu} P_L \tau)$	0.06	3.2 TeV	$B \rightarrow X_s \gamma$
$(\bar{s} \sigma^{\mu\nu} P_R b)(\bar{\tau} \sigma_{\mu\nu} P_R \tau)$	0.09	2.8 TeV	$B \rightarrow X_s \gamma$

Table 1: Model-independent limits on the Wilson coefficients of $(\bar{s}b)(\bar{\tau}\tau)$ operators. The second (third) column shows the limit on $C_i(m_b)$ (the bound on the suppression scale Λ assuming a coupling strength of 1).

is provided in Figure 3. From the left panel one concludes that $\mathcal{B}(B^+ \rightarrow K^+ \tau^+ \tau^-) < 1.3 \cdot 10^{-3}$, corresponding to an improvement of the present upper limit by a factor of 2.5, would allow to set a bound on $C_{S,A}(m_b)$ that is as good as the one that follows at present already from $B_s \rightarrow \tau^+ \tau^-$. As can be seen from the right panel, in the case of $C_{V,AB}(m_b)$, limits of $\mathcal{B}(B_s \rightarrow \tau^+ \tau^-) < 1.7\%$ and $\mathcal{B}(B \rightarrow X_s \tau^+ \tau^-) < 0.7\%$ are needed to be competitive with $B^+ \rightarrow K^+ \tau^+ \tau^-$. The quoted limits correspond to improvements of our current knowledge of the relevant B -meson branching ratios by a factor of 1.8 and 3.6, respectively. Finally, for what concerns $C_{T,A}(m_b)$, even improvements of the direct constraints by a factor of more than 10 are not sufficient to beat the indirect constraint arising from $B \rightarrow X_s \gamma$.

4 Effects of $(\bar{s}b)(\bar{\tau}\tau)$ Operators in Γ_{12}^s

The off-diagonal element of the decay-width matrix is related via the optical theorem to the absorptive part of the forward-scattering amplitude which converts a \bar{B}_s into a B_s meson. Working to leading order in the strong coupling constant and Λ_{QCD}/m_b , the contributions from the complete set of operators (14) to Γ_{12}^s is found by computing the matrix elements of the (Q_i, Q_j) double insertions between quark states. Such a calculation⁷ leads to the results

$$\begin{aligned}
(R_\Gamma)_{S,AB} &< 1 + (0.4 \pm 0.1) |C_{S,AB}(m_b)|^2, \\
(R_\Gamma)_{V,AB} &< 1 + (0.4 \pm 0.1) |C_{V,AB}(m_b)|^2, \\
(R_\Gamma)_{T,A} &< 1 + (0.9 \pm 0.2) |C_{T,A}(m_b)|^2,
\end{aligned} \tag{16}$$

where the quoted uncertainties are due to the error on $(\Delta\Gamma_s)_{\text{SM}}$ as given in (4). Employing now the 90% CL bounds on the low-energy Wilson coefficients given in Table 1, it follows that

$$(R_\Gamma)_{S,AB} < 1.15, \quad (R_\Gamma)_{V,AB} < 1.35, \quad (R_\Gamma)_{T,L} < 1.004, \quad (R_\Gamma)_{T,R} < 1.008. \tag{17}$$

These numbers imply that $(\bar{s}b)(\bar{\tau}\tau)$ operators of scalar (vector) type can lead to enhancements of $|\Gamma_{12}^s|$ over its SM value by 15% (35%) without violating any existing constraint. In contrast, contributions from tensor operators can alter $|\Gamma_{12}^s|$ by at most 0.8%. These numbers should be compared to the best-fit solution for R_Γ as given in (12). From the comparison it immediately becomes apparent that absorptive new physics in Γ_{12}^s in form of $(\bar{s}b)(\bar{\tau}\tau)$ operators cannot provide a satisfactory explanation of the anomaly in the dimuon charge asymmetry data observed by the DØ collaboration. This is a model-independent conclusion that can be shown to hold in explicit models of new physics with modification of the $b \rightarrow s \tau^+ \tau^-$ channel such as leptoquark scenarios or Z' models.⁷

5 Conclusions and Outlook

Motivated by the observation that the anomalously large dimuon charge asymmetry measured by the DØ collaboration, can be fully explained only if new physics contributes to the absorptive

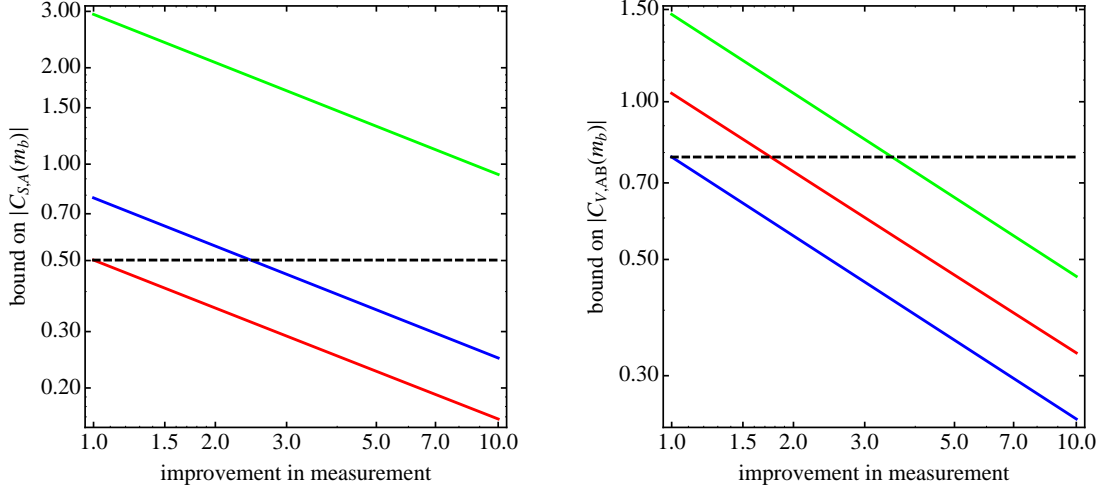


Figure 3: Left (Right): Bound on $C_{S,A}(m_b)$ ($C_{V,AB}(m_b)$) from improved determinations of $\mathcal{B}(B_s \rightarrow \tau^+\tau^-)$ (red), $\mathcal{B}(B \rightarrow X_s \tau^+\tau^-)$ (green), and $\mathcal{B}(B^+ \rightarrow K^+ \tau^+\tau^-)$ (blue). The dashed lines indicate the presently best bound.

part of the $B_{s,d}-\bar{B}_{s,d}$ mixing amplitudes, we have presented a model-independent study of the contributions to Γ_{12}^s arising from the complete set of dimension-six $(\bar{s}b)(\bar{\tau}\tau)$ operators. Taking into account the direct bounds from $B_s \rightarrow \tau^+\tau^-$, $B \rightarrow X_s \tau^+\tau^-$, and $B^+ \rightarrow K^+ \tau^+\tau^-$ as well as the indirect constraints from $b \rightarrow s\gamma$, $b \rightarrow s\ell^+\ell^-$, and $b \rightarrow s\gamma\gamma$, we have demonstrated that only the Wilson coefficients of the tensor operators are severely constrained by data, while those of the scalar and vector operators can be sizable and almost reach the size of the Wilson coefficient of the leading current-current SM operator. It follows that the presence of a single $(\bar{s}b)(\bar{\tau}\tau)$ operator can lead to an enhancement of Γ_{12}^s of at most 35% compared to its SM value. Since a resolution of the tension in the B_s -meson sector would require the effects to be of the order of 300% (or larger), the allowed shifts are by far too small to provide an satisfactory explanation of the issue. We emphasize that after minor modifications, our general results can be applied to other dimension-six operators involving quarks and leptons. For example, as a result of the 90% CL limit $\mathcal{B}(B^+ \rightarrow K^+ \tau^\pm \mu^\mp) < 7.7 \cdot 10^{-5}$,¹³ the direct bounds on the Wilson coefficients of the set of $(\bar{s}b)(\bar{\tau}\mu)$ operators turn out to be roughly a factor of 7 stronger than those in the $(\bar{s}b)(\bar{\tau}\tau)$ case. Possible effects of $(\bar{s}b)(\bar{\tau}\mu)$ operators are therefore generically too small to lead to a notable improvement of the tension present in the current $B_{s,d}$ -meson data. Similarly, a contribution from $(\bar{d}b)(\bar{\tau}\tau)$ operators to Γ_{12}^d large enough to explain the A_{SL}^b data is excluded by the 90% CL bound $\mathcal{B}(B \rightarrow \tau^+\tau^-) < 4.1 \cdot 10^{-3}$.¹⁴ Naively, also $(\bar{b}d)(\bar{c}c)$ operators are heavily constrained (meaning that their Wilson coefficients should be smaller than those of the QCD/electroweak penguins in the SM) by the plethora of exclusive B decays. A dedicated analysis of the latter class of contributions is however not available in the literature.

Our model-independent study of non-standard effects in Γ_{12}^s can readily be applied to explicit SM extensions involving leptoquarks or Z' bosons. In fact, the pattern of deviations found in these scenarios resembles the one of all new-physics model with real $r_{\text{NP}} = (M_{12}^s)_{\text{NP}}/(\Gamma_{12}^s)_{\text{NP}}$, for which it can be shown that the measurement of ΔM_s generically puts stringent constraints on both $\Delta\Gamma_s$ and a_{fs}^s . These bounds turn out to be weakest if the ratio r_{NP} is positive and as small as possible. Since on dimensional grounds r_{NP} scales as the square of the new-physics scale, this general observation implies that SM extensions that aim at a good description of the Tevatron data should have new degrees of freedom below the electroweak scale and/or be equipped with a mechanism that renders the contribution to M_{12}^s small. Furthermore, models in which $(M_{12}^s)_{\text{NP}}$ is generated beyond Born level seem more promising, since in such a case r_{NP} is suppressed by a loop factor with respect to the case where $(M_{12}^s)_{\text{NP}}$ arises already at tree level.

The above discussion implies that a full explanation of the observed discrepancies is not even possible for the most general case $(M_{12}^s)_{\text{NP}} \neq 0$ and $(\Gamma_{12}^s)_{\text{NP}} \neq 0$. Numerically, one finds that the addition of a single $(\bar{s}b)(\bar{\tau}\tau)$ vector operator giving $(R_\Gamma)_{V,AB} = 1.35$ on top of dispersive new physics with $(M_{12}^s)_{\text{NP}} \neq 0$, can only improve the quality of the fit to the latest set of measurements to $\chi^2 = 1.4$ compared to $\chi^2 = 3.5$ within the SM. This might indicate that the high central value of A_{SL}^b observed by the DØ collaboration is (partly) due to a statistical fluctuation. Future improvements in the measurement of the CP phase $\phi_{J/\psi\phi}^s$ and, in particular, a first determination of the difference $a_{fs}^s - a_{fs}^d$ between the B_s and B_d semileptonic asymmetries by LHCb, are soon expected to shed light on this issue, and are of utmost importance in order to answer whether or not there is new physics hiding in the $B_{s,d}$ -meson sector.

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